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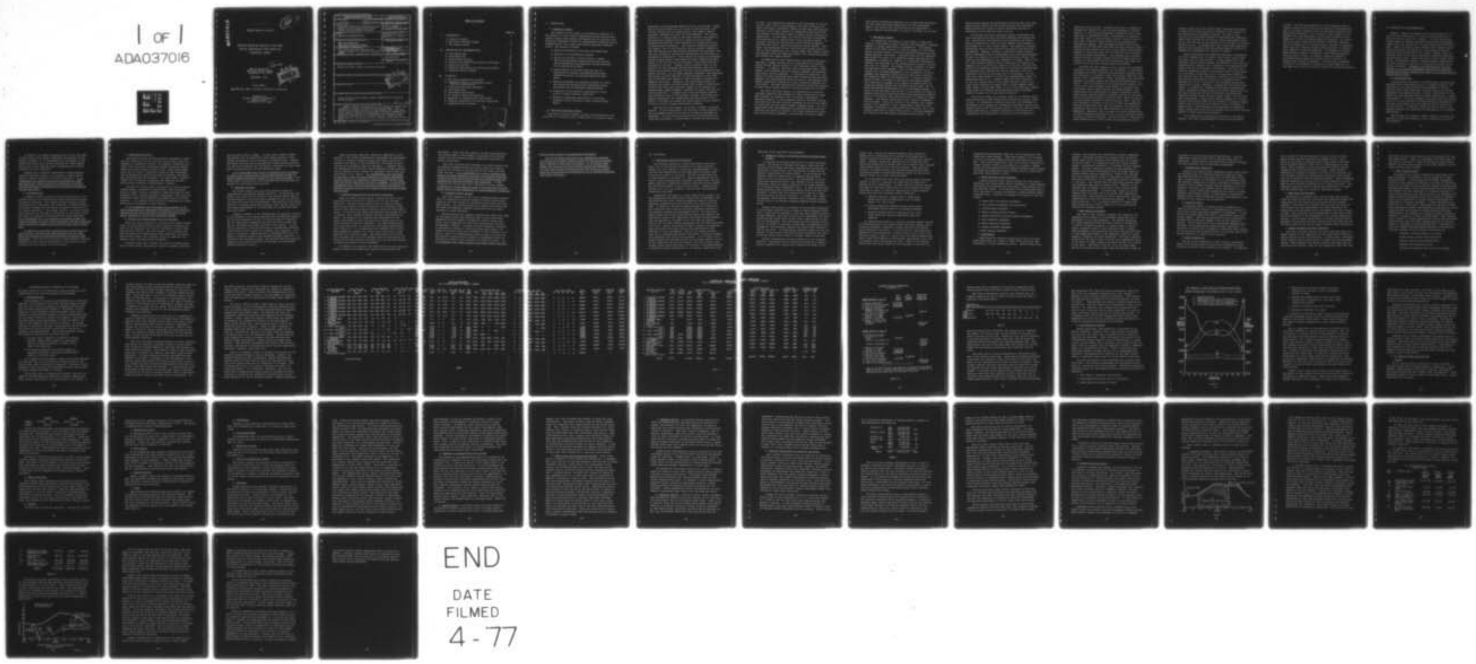

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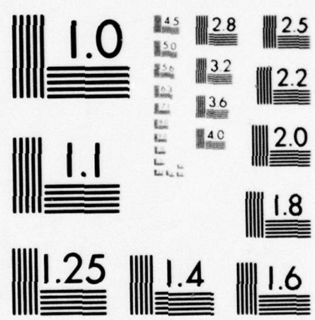

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TECHNICAL REVIEW AND ANALYSIS OF THE TOTAL UTILITY DEMONSTRATION PLANT DESIGN AND OPERATIONAL CONCEPT

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NMD and Associates,
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September, 1976

Final Report

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Report presents an analysis of the design and operational concept of a total utilities demonstration plant. The evaluation includes analysis of load demand data, instrumentation system, design and operational criteria, problem areas which may be encountered in proceeding to prototype design, potential application of automated control system and the application of the total utilities concept to military facilities.

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I. INTRODUCTION

A. Purpose of Report

The purpose of this report is to present an analysis of the design of a total utility demonstration plant and the operational concept and existing load demand data to ascertain that sufficient flexibility exists to experimentally determine design characteristics and criteria and optimum operating characteristics. The analysis includes:

a. Review and analysis of existing load demand data.

b. Analysis of instrumentation systems.

c. Review and analysis of plant design to insure that prototype design characteristics and criteria can be established experimentally through operation of the demonstration plant.

d. Identification of problem areas that may be encountered in scaling from demonstration plant designed operation to prototype design and operation.

e. Review and analysis of operating criteria to insure that operating characteristics optimizing energy utilization can be determined experimentally.

f. Evaluation of the potential application of total utility concepts military facilities.

g. Analysis of potential application of utilities automated control systems on total utilizied plant design.

B. The Total Utilities Concept

The total utilities concept involves the furnishing of all utilities to a facility from a single plant as a means of more

efficiently using available energy from our fuel sources. These utilities would consist of all or part of the following: electricity, heating and air conditioning, water supply, sewage treatment, domestic hot water and trash disposal. The current practice is to obtain most of the above services from separate, non-affiliated corporate entities whose plants are widely separated and who have little incentive for cooperative action in waste energy utilization. Most electric generating plants, for example, are of large capacity and are remotely located so that even though vast waste energy quantities are available, the cost for collection, storage and distribution of such energy to consumers is prohibitive. Great amounts of energy are dissipated through cooling water, stack gases and power transmission which result in the loss of up to 60 percent of the energy initially available in the fuel. Another obvious resource waste is the practice of trash disposal through open burning, land fill or incineration without extraction and use of the considerable heat energy available. It is rather apparent therefore, that combining the utility service functions in close proximity to each other and to the load could result in major increases in energy consumption efficiency. Basically, the cycle would consist of accumulating energy now being wasted such as heat in stack gases, lube-oil and trash and using this energy in the heating, air conditioning, sewage treatment, domestic hot water and water recycling processes. By keeping the utility processes together and relatively close to the ultimate consumer, the capital and energy requirements for transmission and distribution can be held to a minimum thus making the system viable from an economic as well as from an energy conservation viewpoint.

The value of this concept to the DOD is evident in several sectors. In field operations, the military is often required to set up complexes which could range up to tens of thousands of personnel. In each case, utilities must be provided which involve the procurement, transportation, storage and distribution

of fuel. Any significant increase in the efficiency of the use of this fuel, such as anticipated by the total utilities concept, could have a beneficial impact on both costs and logistics. The DOD is also often involved in constructing facilities that are remotely located where access to public utility services is impractical. In such cases, all utility services are provided and maintained as an integral part of the military complex. In the past, designs for the utilities were evolved as separate entities with little regard for potential energy savings. Here again, the application of the total utilities concept would result in fuel conservation and, in many cases, even reduce initial and operating costs by requiring smaller fuel storage facilities and reduced fuel supply demands.

In CONUS base or post construction, the regular DOD policy has been to supply heating and air conditioning to buildings either through central plants or from individual units in each building. In general, services such as electrical power, water supply, trash disposal and often sewage treatment are purchased from nearby utility companies. In barracks and industrial complexes and other facilities where small central plants are being planned, full consideration should be given to the potential for energy conservation offered by a total or partial combined utilities plant. The same consideration should be given for projects in which major rehabilitation of utility services are involved.

The total utilities system is a combination of currently available materials and equipment so that no material or equipment research is necessary prior to project construction. A possible exception to this statement would be the small incinerator which may not meet emission standards set up by some states or localities and the advance sewage treatment system. It is in these areas that some compromise by environmentalists would be justified and should be pursued. The energy conservation equipment involves heat exchangers, heat storage facilities, pumps,

distribution systems and controls, all of whose characteristics are well known and whose operations are fully predictable. Thus if the various load fluctuations can be determined, a fairly accurate determination of overall efficiency can be made.

C. The Energy Problem

In considering the content of this report, a short discussion of the general energy situation and Department of Defense efforts in energy conservation is appropriate. The embargo action of the OAPEC nations on crude oil exports to the United States and other western countries highlighted dramatically our energy resource limitations. Although scientists and engineers have warned for years of an impending energy shortage and our dependence on foreign oil imports, no constructive planning or activity was undertaken by the industrialized nations to define and solve the problem. The embargo served, therefore, at least one important useful purpose - that of demonstrating to our country the increasing dependence of our standard of living on abundant and inexpensive energy sources from foreign nations. The immediate impact of the embargo was, of course, economic in nature as well as creating a shortage of petroleum products. This involved an increase in our balance of payment deficits, increased gasoline prices and increased utility costs, all of which contributed substantially to an inflationary economy. In order to meet the short term crisis, our government initiated a mandatory petroleum allocation program and conservation measures such as a 55 mile per hour speed limitation on federally funded highways. The Federal Energy Office was created to implement these programs. Since the lifting of the embargo and a general easing of the immediate crisis, considerable effort has been expended to evaluate our energy needs and resources with a view toward establishing a viable energy policy, reducing dependence on foreign oil and developing alternate energy sources. The

Federal Energy Agency was established to provide short and long range energy planning and the Energy Research and Development Administration was formed to direct activities relating to developing new and improved energy sources.

In the past few years, numerous studies, evaluations and resulting predictions have been made regarding the energy problem. Although the intricacies of fuel production and distribution throughout the world are very complex, the statement of the problem is, in fact, quite simple. The supplies of fossile hydrocarbon fuels in the world are limited and eventually will be depleted. Somehow, therefore, alternative energy sources must be developed within a predictable time frame and preferably as soon as possible, or we can anticipate severe economic disruptions and degredation of our standard of living. Here in the U.S. most analysts predict that our petroleum and natural gas supplies will be practically depleted by the year 2000 with gas limited to residential heating and oil limited to transportation. Our enormous coal supplies will buy us additional time, but eventually reliance on coal must also be eliminated. For the long term, there appear to be only two inexhaustible sources of energy available to us - nuclear fusion and solar radiation. Of the two, nuclear fusion is the most practical since it provides large quantities of energy from a single compact source. Solar energy, on the other hand, in all of its forms must require large areas of collection and exceptionally high investment capital to permit use of the energy collected.

For the near term, our national policy is to achieve energy self-sufficiency by 1985 which nearly everyone now agrees, cannot be done. In attempting to achieve this goal, the government is proceeding with a program for stimulating aggressive exploration on-shore and off for oil and gas, while at the same time stressing energy conservation, increased efficiency in the conversion, transmission and consumption of energy and the development of

alternate energy sources. Although this effort is primarily economically inspired to free us from dependence on foreign imports, it also serves the purpose of providing time to proceed with an intermediate phase of development of resources which must carry us until breeder reactors, nuclear fusion or some other unlimited energy sources can be developed and successfully applied. The intermediate phase could be well underway by the 1985-1990 time frame and would include several hundred nuclear fission and coal or coal product fired plants capable of furnishing about 30 to 50 percent of our national electrical energy requirements. The expanded use of nuclear fission reactors, breeder reactors and coal should help us to achieve our self-sufficiency until beyond the year 2000 when nuclear fusion and solar energy should be available.

Although the above appears to be a logical and achievable solution to our energy problems, our government is justifiably proceeding with major research and development programs involving production of synthetic liquid and gaseous fuels from coal and oil shale, development of solar, geothermal, wind and ocean gradients as energy sources and controlled thermonuclear research. With the exception of the thermonuclear process, none of the above sources appear to be capable of providing any significant impact toward solving our energy problem. Coal gasification and liquification at current technology levels would require massive capital investment and use of vast quantities of natural resources (coal and water) simply to make up our anticipated shortfall of gas by the year 1990. Even the most optimistic estimates of our use of solar and geothermal sources indicate that less than two percent of our energy requirements could be met by these processes by the year 1990. Apparently, therefore, what are needed are major breakthroughs in basic technology which may or may not occur and which cannot be forecast with any accuracy. We must continue to develop our known capabilities to their fullest by expanding our use of

nuclear fission and coal burning plants and should not gamble on what may be overly optimistic estimates of the results of our research and development programs. By 1985, if the fission plants now being planned or constructed are completed, about thirty percent of our electric power requirements could be met from this source with savings in oil of about six million barrels per day. An enthusiastic coal fueled power generation program could probably match the nuclear capacity and help us become free of dependence on foreign oil imports.

Energy conservation and improved conversion, transmission and use of energy must, of course, play a major role in both our short and long term efforts. A large proportion of our available energy is being wasted, particularly in the fields of transportation, electric power generation and transmission and heating and air conditioning of structures. The use of the internal combustion engine to drive heavy autos at high speeds is an extremely inefficient use of our petroleum resources. Our electric power and transmission facilities are so designed that overall efficiencies of only 25 to 30 percent can be achieved with up to 70 percent of the available energy being dissipated in stack, radiation, transmission and cooling water losses. In industrial, commercial and family housing structures, significant energy savings could result from energy conservation design and the use of materials, insulation and fenestration which would minimize energy losses. We feel that fuel requirements in these areas could be reduced up to twenty percent with minimum impact on our standard of living by taking actions such as limiting auto weights, strict enforcement of speed limits, using insulation and fenestration to minimize energy losses and the use of new concepts such as total utilities plants in future construction projects.

It is important in considering solutions to the energy problem, that full acknowledgement be made of environmental

factors. The long term objectives to free ourselves from reliance on fossil fuels should be welcomed by environmentalists who are currently concerned with air pollutants resulting from hydrocarbon combustion. For the shorter term, however, it is apparent that some concessions must be made to permit the expanded use of coal by relaxing emission standards. For nuclear plants and their supporting facilities, statistics indicate that the probability of a serious nuclear accident is extremely remote and that radiation during normal operation is insignificant compared to natural background. The disposal of nuclear waste material remains a problem for which some satisfactory solution must be found. In general, excessive demands of environmentalists should not be permitted to obstruct our nuclear-coal resource development. For some time, reasonable trade-offs are necessary to provide our energy needs and, at the same time, protect us from the effects of excessive pollution.

II. CONCLUSIONS AND RECOMMENDATIONS

General: There is no question that fuel savings will result from the installation of a total utilities plant on a military facility such as Ft. Belvoir. In fact, preliminary figures based on computer estimates and engineering judgement suggest that fuel savings of 30 to 40 percent should be achievable. There are several areas, however, which require actual plant construction and operation to determine the economic viability and practicality of the system. Though inital construction costs can be fairly accurately estimated, operation and maintenance costs, operational skill levels, system reliability, environmental impacts, internal systems compatibility and plant flexibility can only be established through actual system performance. <u>Because of the high potential for fuel savings, it is strongly recommended that action to construct, operate and analyze a demonstration plant at a military facility proceed without delay</u>.

A. Load Demand Data

Load profiles for heating, air conditioning and electrical equipment were established by use of a computer program. The configuration of these profiles can be assumed to be quite accurate since these loads tend to follow closely the outdoor temperature and humidity trends. However, some errors in load demand and load characteristics are quite possible due to building operation. It is not uncommon on military bases for thermostats to be re-set beyond the limits defined by the designer or for doors and windows to be left open during the heating and cooling seasons. In addition, diversity factors used in many computer programs are considered by some experts to be somewhat questionable.

The profiles for lighting, sewage, domestic hot water and quantity of trash were based on current engineering practice and judgement.

In general, the loads estimated by the A-E for the demonstration plant design appear reasonable and adequate for the purpose intended. It is anticipated that the degree of load demand and load profile accuracy required for future design will be one of the important basic determinations of actual demonstration plant operation.

USAFESA has an excellent opportunity to check computer generated profiles as part of its program of taking actual loads on specific buildings on military facilities. It is recommended that computer profiles be developed for those same buildings. Where significant differences are evident, the reasons should be determined and the computer programming revised accordingly.

B. Instrumentation

A computer assisted control and monitoring system is considered essential for demonstration plant operation and proper information gathering. The computer system proposed includes the capability of monitoring each component, a command function, an operator terminal and the ability to provide a print-out of all system information. The system, however, is oriented toward plant operation and includes no indication of continuous recording which for analytical purposed would be highly desirable. It is recommended that, as a minimum, the system include continuous recording of overall plant efficiency, all main individual inputs required to compute plant efficiency and outdoor weather data.

In addition to the above (although not a specific part of plant design), recording tape instrumentation for all loads should be installed in individual buildings of specific types and groups. This will not only serve to check computer generated profiles, but will permit establishment of accurate daily and seasonal diversity factors for future design.

C. Plant Design Criteria

New design criteria regarding specific equipment is generally not required for total utilities plants since almost all equipment is standard in nature. Two possible exceptions are a small trash incinerator and special sewage treatment elements needed to produce potable recycled water. Major plant components such as boilers, generators, pumps and heat exchangers can be selected and rated on the basis of industry and government specifications and standards. For these items, characteristics such as capacity, efficiency and operation are well known and are included in manufacturers' catalogs.

The type of criteria which is desired will involve general system concept, selection of prime movers, types of heating mediums, extent of plant flexibility, number and types of major equipment items, stand-by equipment requirements, operating and maintenance needs and reliability and compatibility of utility segments. It is expected that the plant as designed will permit satisfactory development of such criteria.

It is recommended that surveilance be maintained on the latest developments by government and industry in the fields of incineration and water recycling to insure inclusion of the latest equipment in future total utilities designs.

D. Scaling from Demonstration Plant to Prototype

Major and rapid fluctuations in load profiles should seldom occur in larger plants serving a great number of buildings because of the relatively low ratio of individual to total loads and diversity factors. Once the accuracy of the profiles has been determined from demonstration plant operation, the smooth profiles will permit more confident design and possibly less complex control and operational procedures.

Increased plant size, however, may result in problem areas such as plant siting, distribution systems, equipment selection

and pollution control systems. In most cases, special studies and analysis will be required to solve these problems so that optimal performance can be achieved at reasonable cost. Developing proper solutions can be accomplished using standard engineering data and procedures with the possible exception of those cases where extreme pollution control demands are made.

It is recommended that, prior to proceeding with the design of large total utility plants, field investigations be made to firmly establish diversity factors for all utility services. This could prevent installation of an oversized plant and distribution systems for the actual loads involved.

E. Operating Criteria

The central control and monitoring system is ideal for experimentally determining optimum operation. By monitoring load levels, fuel usage and the electrical and thermal energy outputs, the performance of each major plant component as well as the overall plant efficiency can be determined. The ability of the central operator to command operational sequences under varying conditions will enable development of criteria which will affect both operation and design.

Inherent, however, in the determination of operating criteria is the necessity for a highly qualified and knowledgeable operator who is fully cognizant not only of the plant and its functions, but who understands completely the total utilities concept and who can anticipate and predict results of his actions. It will also be necessary to provide some means of documenting reasoning and results in such a manner as to permit future analysis. Initially, a sequence of operations must be developed which will be based on estimated profiles and standard equipment operation. As deviations from estimates appear, new and more efficient operation sequences will evolve which will be the basis for formulating optimal operating criteria.

Along with plant operation (though not addressed in plant design) is the further documentation requirement for maintenance. In order to prepare economic analysis for future plants and to establish the degree of plant reliability, the extent of maintenance and maintenance costs are necessary. A complete log of all maintenance work and costs should therefore be kept together with an analysis of the reasons for equipment failure when such maintenance is not routine. Our recommendation for this phase of the work is that the plant operator be a highly specialized utility engineer or a specially trained operator who will work under the direct supervision of such an engineer. It is further recommended that a system maintenance records be devised and if possible included as part of the computer system for easy storage and retrieval.

F. Potential Applications for Military Facilities

There are three obvious sectors in which the use of total utilities plants would be of extreme value to the military. These are: military installations which are remotely located and for which public utility services are not available, bases serving field operations during military action and fixed facilities. In the first two cases, the provision and storage of fuel is always a major logistics problem involving considerable expense. The potential for reducing fuel requirements to the extent anticipated by the total utilities concept should be of great interest to military commanders. For applications other than fixed facilities (if results are verified by demonstration plant operation), it is recommended that standard total utility plant designs be prepared for various sized facilities to meet possible future military needs. The plans would serve to mitigate the many utility service problems which surfaced during the Korean and Vietnam conflicts and which were the expressed concern of almost every major military commander.

In addition to the above, the installation of total utilities plants in many of our CONUS bases appears both practical and

desireable. Aside from fuel savings, the DOD can demonstrate the effectiveness of the concept to both public and private sectors and thus encourage general adoption of this form of energy conservation.

The total utilities plant concept is of such a nature that an existing standard heating and cooling plant can often be modified and expanded to include many of the total utilities plant features. <u>It is recommended that future standard plant designs for CONUS therefore anticipate the possible conversion to total utilities plants and provide the necessary space and compatibility features to permit easy alteration</u>. In many instances this can be done with a minimum of initial expense. <u>In addition, a survey should be made to determine what existing plants would be likely candidates for easy inexpensive conversion</u>.

G. <u>Automated Control Systems</u>

The recent emphasis on the use of automated control systems (ACS) for operation of utility systems on military facilities requires that such systems be considered during total utilities plant design. The control systems will usually not affect overall plant and equipment capacity requirements but may impact seriously on plant operation.

The ACS systems will normally significantly change the shape of the overall plant load profiles which in turn will affect operations such as timing of incinerator firing, boiler operation, use of absorption or electrical refrigeration and optimum equipment loading. It would be highly desirable, therefore, to determine in advance of final utilities plant design, the degree and extent of ACS to be installed in the structures to be served. Where this determination cannot be made, the plant design should be sufficiently flexible to accommodate future ACS installation without major disruption of plant efficiency. <u>It is recommended that, where possible, ACS installations and total</u>

utility plant designs be accomplished concurrently.

For new buildings where ACS is not immediately installed, the design and equipment should be such that ACS can be accepted with a minimum of down time and expense. It is further recommended that future construction design include the possibility of solar assited space conditioning and that fresh air requirements be re-evaluated and established as low as possible consistent with health and safety.

III. DISCUSSION

A. DOD Energy Conservation Program

As indicated previously, energy conservation must play a major role in the eventual solution of our energy problems. Perhaps the best example of significant accomplishment in this area has been demonstrated by the Department of Defense (DOD) in the short period of two years. The DOD consumes about two to three percent of the total U.S. energy requirements and its usage is quite representative including transportation, housing, power production, industrial production and other energy consuming activities similar to the civilian sector. Energy sources include coal, oil, gas, propane, aviation fuels and purchased electricity and steam.

Recognizing the need for a sound conservation program, the DOD established the Defense Energy Task Group in September, 1973 and followed with other internal management teams to identify problems, establish goals and coordinate the conservation program. In addition, the DOD has been involved in coordination and cooperation with industry and other government agencies in the national research and development effort. By taking some rather simple and obvious conservation actions and reducing the operational tempo of the Department, the overall energy consumption was reduced by 25 percent in FY 1974 over the baseline year of 1973 and this reduced consumption rate is being maintained in FY 1975. During this period, we were fortunate to experience some mild winters and cool summers which contributed to the reduction in fuel consumption. Most of the savings, however, were due to increased operational efficiency, a decline in ammunition production and fewer flying missions. It is evident that a proper managed and operated program could produce similar results in the industrial and civilian sectors. We firmly believe that further energy usage reductions will surface as continued emphasis is placed on energy conservation in the design, construction and

operation of new facilities and equipment.

B. Judgmental Factors in Considering Total Utilites Applications

In considering possible application of a total utilities project, the planner or designer must keep in mind that the sources of waste energy are those involved in the processes of production of electricity, the incineration of waste and the possible incineration of sewage sludge. In some areas of the country, plentiful electricity is produced through hydroelectric, coal or nuclear plants. The installation of an oil fired power generation plant, even though it be of very high efficiency, would not appear justified if our prime objective is to conserve scarce hydrocarbon fuels. In other jurisdictions, large municipal trash incineration energy plants have been constructed, in which case the incineration of trash in a total utilities plant may not be justified. In either case, however, the planner could consider a modified total utilities concept in which one of the two heat producing elements might be eliminated.

Another major factor to consider is the climatic conditions of the project location since in order to obtain maximum efficiency, a load must be available to use the waste energy collected. In warm climates, there may be little or no requirement for heating during the winter and in colder areas, there may be no need for air conditioning. This would mean that for periods of up to five or six months of the year, energy must be dissipated to the atmosphere, thus seriously reducing the conservation effectiveness of the plant. No economically efficient method of long term storage of heat has yet been devised which could make the total utilities concept fully viable in extreme climatic conditions.

Another consideration involves operation of the proposed facility. Facilities such as industrial operations or administrative complexes will normally be occupied only eight to ten

hours a day. During the occupied periods, heavy electrical demand can be anticipated with attendant large quantities of energy available for meeting heating or air conditioning requirements. However, during the remaining 12 to 14 hours per day, electrical demand may be minimal while the structure still requires large energy quantities for climatic control. Under such conditions, it becomes evident that projects which provide widely fluctuating loads for protracted periods during the day are not ideally suited for a total utilities plant.

It is estimated that over 500 total energy plants are operational in the U.S. involving the production of electricity, heating and air conditioning. No total utilities plants, however, are known to have been constructed so it would appear desirable, initially at least, to restrict construction to those projects which would meet the following general conditions:

a. Projects should be located only in those areas where electricity is generated by use of fossil fuels, i.e., oil or gas.

b. Projects should be located in areas where winter and summer energy loads are reasonably balanced.

c. Projects should involve a suitable mix of structures which will avoid extreme daily load fluctuations.

An ideal project would be a military barracks complex located in the mid-section of the country which contained housing, administration buildings, hospitals, storage facilities and messing and recreational facilities. In this situation, good electrical demand can be anticipated for a large portion of the 24 hour day. The mess facility, which is a major load, will begin operation between 4 and 5 AM followed by the barracks load between 6 and 8 AM as personnel arise and prepare for work. Loads in the administrative and work areas follow for the remainder of the day, and

barracks and recreational loads fill in the evening and late hours until about midnite. There would appear to be a period of only 3 to 4 hours where electrical load would be at a minimum. Even during these hours, some load would be available for street lighting, security and parking lot lighting. Needed energy for this period could be supplied through limited storage of excess heat generated during the day as well as heat available from incineration of trash.

C. Total Utilities Plant Equipment

A total utilities plant should contain the major energy conversion and energy using items of equipment in close proximity and should be so designed and controlled to make maximum use of the available energy. From the plant will be delivered electricity, hot water or steam, chilled water, sewage effluent and/or re-cycled water. The plant in essence will consist of the following:

a. Prime mover and electric generator.

b. Heat recovery equipment for prime mover.

c. Chilled water generator.

d. Fossil fueled auxiliary boiler.

e. Trash incinerator and heat recovery equipment.

f. Heat rejection equipment.

g. Water recycling equipment.

h. Sewage treatment equipment.

i. Heat storage equipment.

1. Prime Movers

Prime movers for electric generation in total utilities plants may be any of a number of types which have been used successfully in small generating plants. These include steam

turbines, gas turbines and reciprocating internal combustion engines. The steam turbines are generally more suited for larger applications and where high temperatures are required by special loads. By exhausting steam from various turbine stages, considerable flexibility is available in heat transfer design. Internal combustion engines are more adaptable to smaller installations particularly where the major loads are comfort heating and air conditioning. Much of the rejected heat from reciprocating engines is absorbed by jacket water and lub-oil which falls in the temperature range of 250 degrees F. and below. Gas turbines are low efficiency machines which have basically been used as peaking units. However, if the rejected heat is useable, their use in total utility plants may be highly desirable. In these units, almost all of the rejected heat is thrown off as relatively high temperature exhaust gases, which permits its use in applications requiring temperatures too high for reciprocating engines. In complex load situations, it is, of course, possible to combine the above prime movers in such a manner as to most efficiently utilize the available energy.

2. Heat Recovery Equipment

The type of heat recovery equipment will depend on the temperature and character of the exhaust medium and the requirements of the using equipment. The exhaust medium may be a high temperature flue gas from a boiler or incinerator, a turbine or engine discharge, an engine jacket or lub-oil cooler, condenser water or steam extracted from a turbine. Using equipment requirements may vary from high pressure steam or high temperature water to low temperature water for direct heating or domestic hot water generation. The basic processes involved are hot gas to water or steam, high temperature water to hot water or steam, steam to hot water and hot oil to steam or hot water. The state of the art in all of these combinations is excellent and in most cases off-the-shelf items are

available to total utilities plant applications. Once the temperature range and mass flow of the waste heat unit is determined, characteristics and quantities of energy available for using equipment can be accurately established.

3. Chilled Water Generators

Selection of chilled water generators in many cases offers an excellent means for balancing electrical and heat loads. The generators may be of the electrical or prime mover drive type (reciprocating or centrifugal) or of the absorption type. The greatest flexibility is usually provided by installing an electric driven machine together with an absorption unit, designed so that they could operate either individually or in parallel. Proper operational sequencing and control of these machines could assist greatly in maintaining a load balance between electric power production and heat requirements so that periods of heat rejection can be minimized.

4. Auxiliary Boiler

An auxiliary boiler is almost always a necessity in a total utilities plant because of the possibility of failure of the electric power generating equipment or switchgear. It also serves to provide imput when there is insufficient waste heat to meet demand. This may be particularly true on week-ends or holidays where electrical demand is low and the weather is extreme. Boiler capacity may vary considerably depending upon the types of buildings being served and their operation. In any case, the boiler must be capable of preventing pipe freezing in the structures being served as well as the plant, and of permitting operation of other utility services.

5. Trash Incineration

The use of heat contained in trash through incineration offers an excellent means of saving often considerable costs involved in private trash collection and disposal. In addition,

it is a means of further balancing loads by firing the incinerator during periods when electrical demand is low. Flexibility of the plant is enhanced since either steam or hot water can be produced through a high range of temperatures and pressures. Major problems involving incineration concern emission regulation and trash processing and firing. Where emission standards are extremely stringent, the cost of air pollution control may make incinerator installation impractical unles exceptions can be obtained from the regulatory bodies. Trash processing, storage, handling and firing will all require analysis to determine the most effective combination for a specific project. Consideration should be given to drying and incineration of sludge from the sewage plant as a source of additional energy.

6. Heat Rejection Equipment

Some method of rejecting heat from the plant must be provided for those periods when the waste heat generated exceeds the requirements of the facilities and the plant's heat storage capacity. Such cases will normally occur during mild spring or fall weather when the requirements for either heating or air conditioning are negligible and yet the demand for electric power is high. Heat rejection may be accomplished in many ways including direct exhaust to the atmosphere or to a stream, evaporative cooling, cooling towers, spray ponds or radiator cooling devices. Equipment and processes for heat rejection are well known and off-the-shelf items can be used for total utilities plant application.

7. Sewage Treatment and Water Recycling

The type of sewage treatment and water recycling plant will depend largely on the composition of the sewage and the degree of purity desired for the recycled water. In most cases, the sewage plant capacity will be small enough to permit the use of packaged plants. Where possible, the design should be such that the sewage plant will provide a load for low temperature waste heat from

the total utilities plant which may not be suitable for other load applications. There is considerable work being done in the field of recycling of water by EPA and the Army Surgeon General and some systems appear to be highly adaptable to the total utilities plant concept.

8. <u>Heat Storage Systems</u>

The amounts and timing of demands for waste heat are of prime importance in determining the efficiency of a total utilities plant. As such demand may be highly fluctuating, the use of heat storage is essential as a means of minimizing plant heat rejection and the resultant thermal efficiency loss. Although many types of heat storage systems have been devised, the simplest and most economical for processes involved in total utility plants is hot water storage in an insulated tank. Storage capacity determination must be a matter of judgement since little information on actual demand fluctuations for structures is currently available. A recent publication prepared by H.W.C. Aamot and G. Phetteplace of the Corps of Engineer Cold Regions Research and Engineering Laboratory is titled "Opportunities and Systems for Energy Storage on Military Installations" and should be of interest to those involved in planning or design of a total utilities plant. This document lists a number of storage systems which are currently available technology and also many other systems which are in various stages of development, testing and research. A follow-on report will consider detailed characteristics of the currently available systems and will evaluate such factors as:

Volumetric and mass density of storage.

Losses during storage and storage life.

Storage capacity and estimated costs.

Charging and discharging rates.

Conversion efficiency into and out of storage.

Attainable degree of recovery out of storage.

The above data will be of particular value as larger and more sophisticated total utilities plants are envisioned.

D. Load Demand Data

The development of accurate load demand data is absolutely essential to the design of the total utilities plant as these data not only affect the capacity of equipment installed but also the entire operational concept of the system. To date there are no data available which will permit simple determination of load profiles although a project sponsered by FESA is in progress which will rectify this problem. This project involves taking actual measurements of loads throughout the year of many standard type military structures. For future projects at different locations, these profiles may be revised to correct for varying outdoor conditions by the use of a properly programmed computer. For current projects, however, the planner or designer has two basic options:

1. To take actual readings of electrical, heating, cooling, sewage, water supply and trash generation on existing buildings or similar buildings in the same area.

2. To develop estimated load profiles based on a thorough evaluation of the many variable which impact on utilities usage.

It is apparent that procedure 1 above is the most desirable and accurate, but will not normally be feasible due to time restrictions and/or construction scheduling. Procedure 2 must, therefore, most often be used, particularly where construction of newly designed buildings is involved.

The initial step in estimating the overall loads for the plant is the development of electrical, heating, cooling and other utility load profiles for each building to be served. A

24 hour profile for each of the load demands should be made for the winter/summer design conditions and for spring or fall. Further, for each of these weather conditions, a profile for a standard work day and for a weekend or holiday should also be made. This means that a total of 18 profiles should be available for each building. In arriving at these profiles, the designer must have detailed knowledge of the type and method of control of the heating and air conditioning systems, the type of domestic hot water heating system, the installed electrical lighting and equipment as well as the anticipated building occupancy and operation.

Computer programs such as E-Cube can be of considerable value in developing load profiles although some limitations are apparent since many programs provide data on an hourly rather than an instantaneous basis and are often not programmed to account for variations in building occupancy. Where a large number of differing types of buildings are being served, however, the computer programs should generally provide adequate data for plant design as diversity will tend to level out extreme demand variations.

After the individual building profiles have been completed, they should be totalized to provide a series of curves which will illustrate consumer demand for work days and holidays for each season of the year. Care should be taken to add incidental loads such as parking lot, security and street lighting where applicable. As these totalized profiles represent the major demands on the plant, an analysis of the relationship of the various energy requirements will permit preparation of alternative concept designs to establish maximum plant efficiency consistent with plant operational concept. In preparing and evaluating these alternatives, the designer must keep in mind that in addition to the actual building demands, energy transmission losses and plant energy requirements must be considered. In

the final analysis, the overall relative demands for the different types of energy will establish the degree of flexibility needed in the plant. This can affect the determination of hot or chilled water storage capacity, size and number of generators, size and operation of the incinerator and other major facets of design.

For the Ft. Belvoir project, there were no actual load profiles available, so the A-E proceeded to develop estimated heating, air conditioning and electrical profiles based on building construction and weather tapes. The domestic hot water and incinerator loads were projected from population and occupancy figures. Table I shows the computer inputs which are required to establish the transmission portion of the load profiles. These inputs include wall, roof and glass areas, lighting and electrical power and occupancy. Table II shows a summary of maximum loads after adding to the transmission loads the outside air, infiltration, sensible and latent loads and applying a diversity factor for the electrical demand. Typical profiles were prepared for winter and summer work days and week ends which included distribution, internal plant and sewage plant loading. These profiles established the overall plant capacity and were instrumental in determining boiler and air conditioning compressor capacities (See Table III).

There is no apparent reason to question the accuracy of the profiles generated based on current knowledge. However, the standard theoretical heat transmission, demand and diversity factors which have been used for years are being found to less than fully accurate when actual consumption is recorded. This is particularly true in the areas of domestic hot water and electrical demand. It is important, therefore, that the profiles used in demonstration plant design be retained and either verified or revised by the information obtained during actual plant operation for use in prototype design. Computer generated

BUILDING DESIGNATION AND TYPE	TOTAL WALL AREA SQ/FT NW	NE	SW	SE	TOTAL GLASS AREA SQ/FT NW	NE	SW	SE	TOTAL INSUL PNL. AREA SQ/FT NW	NE	SW	SE	TOT LIG KW
1. EM BARRACKS BUILDING 3 MODULES	5286	3672	3672	5286	635	1998	1998	947	317	759	891	346	18.
2. EM BARRACKS BUILDING 3 MODULES	5286	3672	3672	5286	635	1998	1998	947	317	759	891	346	18.
3. EM BARRACKS BUILDING 3 MODULES	5286	3672	3672	5286	739	1998	1998	843	346	891	891	337	18.
4. EM BARRACKS BUILDING 3 MODULES	5286	3572	3672	5286	635	1998	1998	947	317	891	891	346	18.
5. EM BARRACKS BUILDING 4 MODULES	6797	4896	4896	6797	1224	2664	2664	1017	442	1188	1188	424	23.
6. EM BARRACKS BUILDING 2 MODULES	3022	2448	2448	3524	612	1332	1332	508	221	594	594	212	12.
7. DISPENSARY GROUP BUILDING	282	662	642	313	84	114	166	43	35	-	--	--	6.
8. BRANCH EXCHANGE BUILDING	710	400	610	640	220	0	60	300	0	0	--	--	14.
9. 3 COMP. ADMIN.(Off.) (Stor.)	533	1944	1256	533	0	0	252	0	0	0	220	--	15. 9.
10. 3 COMP. ADMIN.(Off.) (Stor.)	1944	533	533	1256	0	0	0	252	0	0	--	220	15. 9.
11. 4 COMP. ADMIN.(Off.) (Stor.)	1674	533	533	2592	336	0	0	0	294	0	--	--	20. 10.
12. 2 BATTALION HDQTRS. & CLASSROOMS	1255	1804	2024	1255	201	510	290	201	0	0	--	--	25.
13. HEADQUARTERS BLDG. REGIM./BRIGADE	2060	720	720	1600	236	96	96	402	104	52	52	78	15.
14. FOOD SERVICE FACIL. BUILDING *	1443 965	1500 0	1259 1259	1443 965	230 230	298 0	666 666	230 230	0	0	--	--	34. 9.
15. UNIT CHAPEL BUILDING	1470	1744	1854	1223	381	442	332	128	0	0	--	--	7.
16. GYM BUILDING (No Air Cond. System)	4450	3627	3554	4652	110	37	110	161	0	0	--	--	51.

* Cooled Area Only

COMPUTER LOADING DATA
TOTAL UTILITIES PLANT - FT. BELVOIR, VIRGINIA

L. AREA	TOTAL	TOTAL	FCU	TOT. MISC.	NO. OF	ROOF		TOTAL SOLAR LOAD (BTU)				SOLAR LO	
SE	LIGHTS KW	NO.	WATTS	MOTORS KW	PEOPLE	AREA SQ/FT	ROOF	NW GLASS	NE GLASS	SW GLASS	SE GLASS	NW	NE
346	18.0	89	14.28	15.5	140	10740	79047	25410	63936	213543	32198	6	15
346	18.0	89	14.28	15.5	140	10740	79047	25410	63936	213543	32198	6	15
337	18.0	89	14.28	15.5	140	10740	79047	29572	63936	213543	28674	7	15
346	18.0	89	14.28	15.5	140	10740	79047	25400	63936	213543	32198	7	15
424	23.8	118	19.91	22.0	184	14320	105395	48988	85248	284724	34564	9	15
212	12.0	59	9.45	11.0	92	7160	52984	24480	42624	142362	17306	9	15
--	6.7	0	0	31.0	10	3195	23643	3360	3648	31040	1462	5	6
--	14.88	0	0	23.5	50	4720	34928	8800	0	11220	10200	14	0
--	15.45	0	0	2.23	45	5402	39975	0	0	0	11764	0	0
	9.10			4.80		8640							
220	15.45	0	0	2.23	45	5402	39975	0	0	64702	0	0	0
	9.10			4.80		8640							
--	20.60	0	0	2.98	60	6910	51150	18480	0	0	0	27	0
	10.30			5.50		11640							
--	25.50	0	0	18.42	96	11989	82724	8040	16320	27438	6834	6	11
78	15.30	23	4.5	13.2	45	3200	23552	9440	3072	17953	13670	14	5
--	34.85	0	0	80.34	340	15172	53406	9200	0	75591	7820	6	0
	9.00			60.6		9675							
--	7.70	18	1.31	12.05	308	8684	39946	12195	11315	49670	3480	11	10
--	51.80	0	0	39.81	--	21357	--	--	--	--	--	2	1

TABLE I

2

LAR LOAD (BTU)			SOLAR LOAD % GLASS					TOTAL	TOTAL SENS.	TOTAL LAT.	TOTAL
NE GLASS	SW GLASS	SE GLASS	NW	NE	SW	SE	ROOF	HEATING BTU	COOLING BTU	COOLING BTU	COOLING BTU
63936	213543	32198	6	15	52	8	19	988330	748312	192806	941118
63936	213543	32198	6	15	52	8	19	988330	748312	192806	941118
63936	213543	28674	7	15	52	7	19	990080	751631	192512	944143
63936	213543	32198	7	15	52	7	19	989960	756975	192512	949487
85248	284724	34564	9	15	51	6	19	1324615	1016449	258228	1274667
42624	142362	17306	9	15	51	6	19	659445	482004	128916	610920
3648	31040	1462	5	6	49	2	38	119780	118221	21524	139745
0	11220	10200	14	0	17	16	53	286191	205995	96774	302769
0	0	11764	0	0	0	23	77	141206	163530	33465	196995
								235675	--	--	--
0	64702	0	0	0	61	0	39	141206	214739	33465	248204
								235675	--	--	--
0	0	0	27	0	0	0	73	183560	214400	44620	259020
								306885	--	--	--
16320	27438	6834	6	11	79	5	59	427270	366629	108295	474924
3072	17953	13670	14	5	27	20	34	220450	178405	35960	214365
0	75591	7820	6	0	52	5	37	2556070	868503	729300	1597803
1315	49670	3480	11	10	42	3	34	395710	329767	144540	474307
--	--	--	2	1	10	3	84	2078385	--	--	--

BUILDING LOAD SUMMARY DATA
TOTAL UTILITIES PLANT - FT. BELVOIR,

BUILDING DESIGNATION AND TYPE	FLOOR AREA SQ/FT	TOTAL BUILDING VOLUME	HEATING LOAD DATA TRANS. LOAD	INFILTR. LOAD BTU	OUTSIDE AIR LOAD BTU	COOLING TRANS. & SOLAR BTU
1. EM BARRACKS BUILDING 3 MODULES	32220	257760	718720	198350	269610	587275
2. EM BARRACKS BUILDING 3 MODULES	32220	257760	718720	198350	269610	587275
3. EM BARRACKS BUILDING 3 MODULES	32220	257760	720468	198350	269610	588480
4. EM BARRACKS BUILDING 3 MODULES	32220	257760	720350	198350	269610	593940
5. EM BARRACKS BUILDING 4 MODULES	42960	343680	962665	264464	361950	791355
6. EM BARRACKS BUILDING 2 MODULES	21480	171840	478469	132232	180975	369450
7. DISPENSARY GROUP BUILDING	3195		88377	21425	31400	79845
8. BRANCH EXCHANGE BUILDING	4720		122400	21425	163800	87750
9. 3 COMP. ADMIN.(Off.)	5402		104270	33427	36936	81480
(Stor.)	8640		136565	99110	--	
10. 3 COMP. ADMIN.(Off.)	5402		104270	33427	36936	132690
(Stor.)	8640		136565	99110	--	
11. 4 COMP. ADMIN.(Off.)	6910	87439	134310	14260	49248	105000
(Stor.)	11640		173175	133710	--	
12. 2 BATTALION HDQTRS. & CLASSROOMS	11989	170864	266600	96095	160670	197290
13. HEADQUARTERS BLDG. REGIM./BRIGADE	9843	98430	157720	62730	47710	101310
14. FOOD SERVICE FACIL. BUILDING	15172	151720	289120	116717	2266950	183620
15. UNIT CHAPEL BUILDING	8684	165606	211030	100530	184680	164720
16. GYM BUILDING (No Air Cond. System)	20781	484384	471670	362577	1606716	--
TOTALS	314338		6715464	2082710	6206411	4651480

TABLE II

LOAD SUMMARY DATA
ANT - FT. BELVOIR, VIRGINIA

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COOLING LOAD DATA			PEOPLE LOAD		ELECTRICAL LOADS	
TRANS. & SOLAR BTU	INFILTR. LOAD BTU	OUTSIDE AIR LOAD BTU	SENSIBLE BTU	LATENT BTU	LIGHTING KW	POWER KW
587275	179625	244515	34300	28700	18.0	15.5
587275	179625	244515	34300	28700	18.0	15.5
588480	179625	244220	34300	28700	18.0	15.5
593940	179625	244220	34300	28700	18.0	15.5
791355	239500	328460	45080	37720	23.8	22.0
369450	119750	163930	22540	18860	12.0	11.0
79845	19405	28440	2450	2050	6.7	31.0
87750	19405	133365	12250	10250	14.9	23.5
81480	30277	33455	11025	9225	15.5	2.2
					9.1	4.8
132690	30277	33455	11025	9225	15.5	2.2
					9.1	4.8
105000	40090	44610	14700	12300	20.6	3.0
					12.1	5.3
197290	87026	142715	21840	10680	25.5	17.1
101310	55770	42380	11025	6975	15.3	10.7
183620	105720	929600	93500	93500	34.9	34.5
					9.0	60.6
164720	91045	167280	69300	32340	7.7	10.5
--	--	--	--	--	51.8	39.8
4651480	1556765	3025160	451935	357925	264.1	345.1

I

2

EQUIPMENT CAPACITY DETERMINATION
FT. BELVOIR, VA.

WINTER OPERATION - Jan. 23	Site Load BTU/HR	Heat Recovery BTU/HR	Usable Load Installed BTU/HR KW
1. Heating Requirement	15,717,000	-	-
2. Domestic Water Requirement	3,507,000	-	-
3. Total Site Requirement	19,224,000	-	-
4. Electric Generation 4-600KW diesel generators, 3 on line- one reserve	-	-	1920 KW
5. Heat recovered from engines- 902 x 4000	-	3,608,000	-
6. Net Heat Requirement	15,616,000	-	-
7. Select 4 boilers, each 5200MBH, 3 on line, one in reserve	-	-	20,800,000 BTU/HR

SUMMER OPERATION - Aug. 19			
1. Refrigeration System-Required 970 x .7 x 12,000	8,148,000	-	-
1-118 Ton centrifugal unit	-	-	1,416,000 BTU/Hr
1-620 Ton absorption unit	-	-	7,440,000 BTU/HR
2. Thermal Requirements 620 tons x 17,000	10,540,000	-	-
3. Domestic Hot Water	3,500,000	-	-
4. Total Site Requirement	14,040,000	-	-
5. Heat Recovered from Engines 1157 x 4000	-	4,628,000	-
6. Net Thermal Requirement	9,412,000	-	-
7. Total Boiler Capacity	-	-	20,800,000
8. Total Refrigeration Capacity	-	-	8,856,000

Based on the above the plant will consist of 4 generators rated 600 KW (actual 480 KW), 4 boilers @ 5200 MBH, one absorption air conditioner @ 620 tons and one centrifugal air conditioner @ 118 tons.

TABLE III

profiles may also be checked for accuracy by comparison with actual profiles now being made on many military installations.

Two items of particular interest were revealed when the computer program was run to cover a period of one full year of operation (See table below).

	PERCENTAGE OF PEAK LOAD OPERATION	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	90-100
HOURS OF OPERATION	Heating	445	970	1069	996	939	694	266	64	0	0
	Cooling	2659	585	454	494	346	143	15	0	0	0
	Electrical	0	0	0	2045	985	330	1935	1640	1205	620

TABLE IV

One item involves the indication that during the air conditioning season, the load was less than 20 percent of the peak for about 70 percent of the time. Because of this, the A-E selected a centrifugal machine to handle this base load and sized the absorption machine to handle the remaining maximum load. This would permit the use of the waste heat under almost all cooling conditions and minimize inefficient heat rejection from the plant.

The other factor is the relationship of recoverable waste heat to the overall plant load. Under maximum heating conditions, recoverable heat amounts to about 18 percent of the plant load while for air conditioning the figure is about 25 percent. These figures indicate that heat rejection from the plant will seldom be required and that large heat storage facilities will not be needed. It further can be assumed that as heating and cooling loads are less than their maximum as will be the case most of the time, the electrical power and lighting loads will not decrease proportionally. This factor, together with the recoverable

heat available from trash and sludge incineration, would suggest that, for a properly designed plant, fuel savings of between 30 and 40 percent should be attainable. This estimate was theoretically verified by the Architect-Engineer as shown in figure 1. Computations were made on a monthly basis for an entire year - with and without the contribution of trash incineration. As indicated, fuel savings with incineration vary from a low of 24 percent during winter operation to a high of about 50 percent during the peak air conditioning season. It is expected that some further improvement would result when demonstration plant data are available and optimum design criteria and operational procedures are developed.

E. Instrumentation Systems

Normal operational instrumentation as required for any boiler, generator, sewage or water supply plant is necessary for the total utilities plant to permit start-up, balancing, operation and shut-down. These instruments are usually of the instantaneous reading type and involve determination of temperatures, gas and liquid flows, pressures and electrical power on major items of equipment such as generators, boilers, condensers, pumps, air conditioners and fans. However, since the total utilities concept is unique and new, it is recommended that additional instrumentation be installed on the first several plants to establish design data for future similar facilities.

Of prime importance is the determination of overall plant efficiency. This requires measurement and recording of energy input to, and energy flow from the plant. Continuous integrating recording meters and instruments should therefore be provided for measuring:

1. Fuel input to generators and boilers.
2. Trash quantity and BTU value to incinerator.
3. Power output from plant to users.

FT. BELVOIR - TOTAL UTILITIES DEMONSTRATION PLANT

ENERGY REQUIREMENT, RECOVERABLE HEAT & FUEL SAVINGS

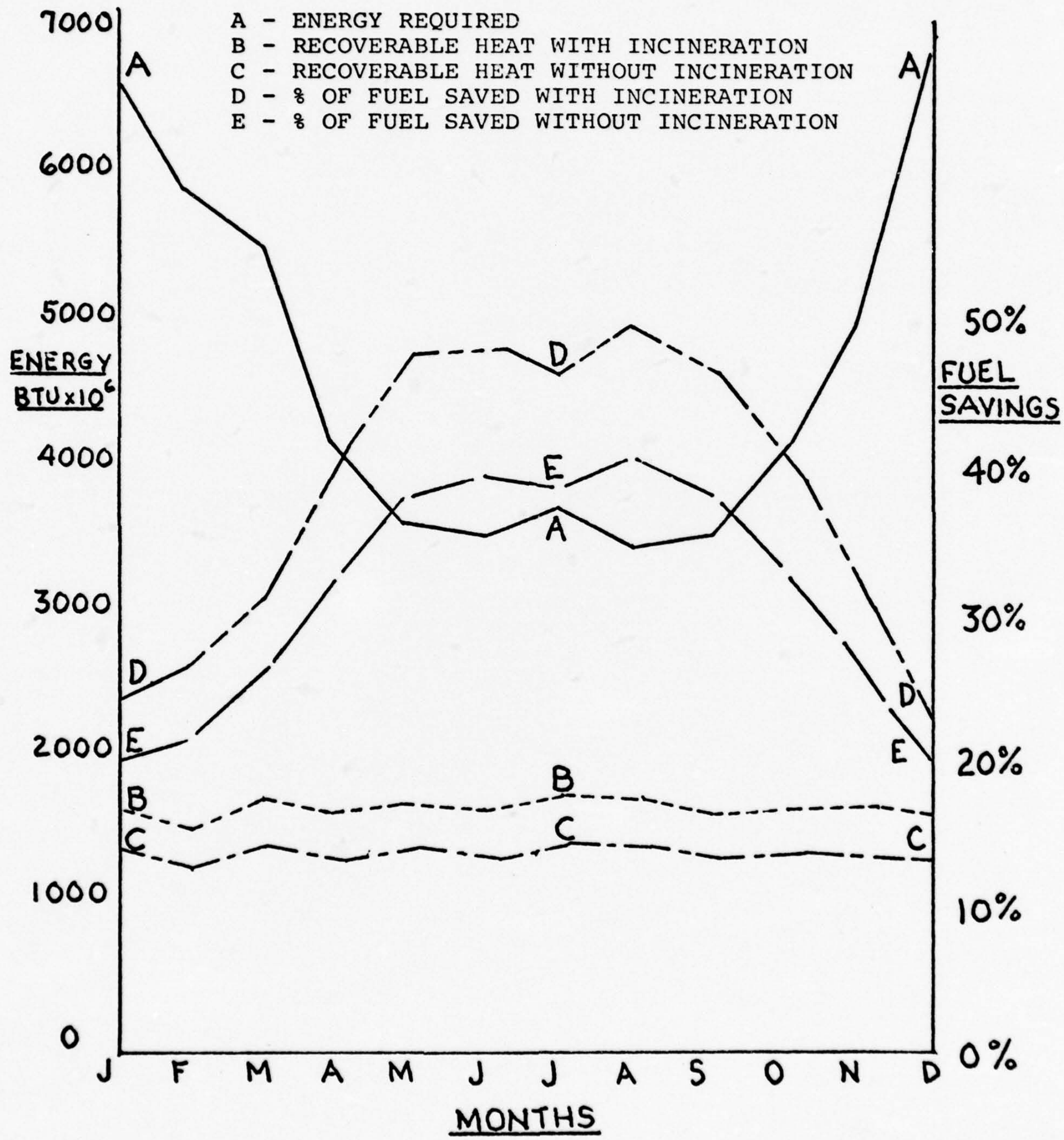


Figure 1

4. Temperatures and flows of steam, hot water, chilled water and other energy transmissive mediums to users.

5. Volumes and temperatures of return hot water, chilled water, condensate or any other energy transmissive mediums.

6. Volume of recycled water from the plant.

7. Volume and character of sewage.

In addition to the above, power, heat and refrigeration to certain processes within the plant should be metered and added to the overall plant output. These involve energy to the sewage treatment equipment and to the water recycling process.

Next in importance is data gathering instrumentation of individual buildings of specific types and groups. This data is essential to provide a basis for development of accurate load profiles and establishing meaningful demand factors for future design. On a typical barracks complex, for example, daily load profiles should be taken for electric power, heating, domestic hot water and air conditioning in several individual barracks buildings, a mess hall, an administration building, a chapel, a ware-house and individual recreational and industrial type facilities. In addition, profiles should be established for entire areas which can be catagorized - such as housing, industrial, administrative, storage and recreational. Analysis of these data over a period of time will permit establishment of accurate daily and seasonaly diversity factors for future design.

Another factor which affects overall plant performance is the extent to which energy is rejected from the plant because of inadequate or unbalanced loads. Energy rejection equipment should, therefore, be instrumented to record time of operation

and quantity of heat rejected. The value of this data is evident since it will serve to point out the specific circumstances under which the plant is operating inefficiently. Documentation of these data should provide a basis for future designs of plants which will provide optimum performance.

Recording instrumentation of plant internal equipment will not normally be necessary since power consumption and heat transfer characteristics are usually readily available from the manufacturer. One major exception is the prime mover which rejects heat often in various ways at different load conditions and for which manufacturer's data may not be available. The design, therefore, should incorporate recording equipment to measure temperature and mass flow of exhaust gases, cooling system and lube oil system at varying loads. This information can be used in future designs to size and specify heat recovery equipment and to develop operating procedures to maximize plant efficiency.

Together with the above recommended instrumentation, provision should be made for weather station data to be continuously recorded. This data should include dry bulb and wet bulb temperatures as well as wind velocity and direction. Correlation of this information with actual loads and diversity factors is essential in site adapting the general design concept for other climatic areas of the country.

F. Ft. Belvoir Design and Operation

1. Design

The Ft. Belvoir plant is designed to serve a 1200 man barracks complex which includes housing, a dispensary, a branch exchange, administration and storage buildings, headquarters and classroom buildings and a chapel, mess and gymnasium. These buildings comprise a total of about 314,000 square feet. Design conditions are as follows:

	Outdoor		Indoor	
SUMMER	$91^{o}F$,DB	$77^{o}F$,WB	$75^{o}F$,DB	50% RH
WINTER	$15^{o}F$,DB		$72^{o}F$,DB	

During the heating season, the maximum heating and domestic hot water load will be about 19 million BTU/Hr with a KW demand of about 900. Recoverable heat during that period from the generators will be approximately 3.5 million BTU/Hr. Additional heat recovery will be available from trash incineration. During the cooling season, the BTU requirements for cooling and domestic hot water will be about 14 million BTU/Hr with a KW demand of slightly over 1150. Recoverable heat during this period from the generators is 4.6 million BTU/Hr plus what is developed from trash incineration.

Hot water at $215^{o}F$ and chilled water at $45^{o}F$ are distributed through separate underground distribution systems to the buildings. Hot water is fed to domestic hot water and building system heat exchangers at each building while chilled water is sent directly to the building chilled water circulating pumps. Based on the above, the A-E selected the following major items of equipment:

a. Engine Generators

Four diesel engine generators were specified with nominal ratings of 600 KW each but derated to 450 KW each because of the high temperature of the cooling water to the engine jackets as required by the heat flow concept. Space was made available for the addition of 2 future units. Generators are medium speed (1200 RPM) to operate at 480 V, 60 Hz and capable of specified performance with a 15 inch water column drop in the diesel exhaust gas discharge due to installation of heat recovery muffler.

b. Boilers

Four hot water boilers are specified. Boilers are oil-fired,

forced draft with a capacity of about 150 HP and designed for a maximum operating hot water temperature of 245°F. Each boiler is equipped with a boiler circulating pump.

c. Refrigeration Units

An absorption water chiller with a capacity of 622 tons will be provided with space for a second unit. An electrically driven centrifugal unit with a capacity of 118 tons is also specified. These units are served by a single roof mounted cooling tower with a capacity of 2760 GPM.

d. Heat Storage

No low temperature heat storage is provided for this plant since computations and load profiles indicate that for a great percentage of the time, there will be a use for the recoverable heat produced by the generators. A high temperature storage tank (350°F to 450°F) is indicated, however, for heat generated by the incinerator. This water will be used for sludge drying and for supplementing normal heating system requirements.

e. Sewage Treatment

Sewage treatment facilities consist of an underground wet well and comminuter, primary and secondary clarifiers, rotating disc contactor, pressure filters, finished water storage and sludge autoclave and centrifuge.

f. Pumps

Three heating distribution pumps are provided, two capable of handling the maximum load and one acting as standby. Two chilled water distribution pumps are indicated, each sized for the full chilled water load and a primary and standby pumps are also indicated for the cooling tower. Other critical items of equipment requiring pumping are also supplied with standby pump capacity.

g. Incinerator

Because of the relatively small quantity of trash available, the incinerator is sized for 6 to 8 hours of daily operation.

h. Oil Storage Tanks

Two underground fuel oil storage tanks sized at 25,000 gallons each are provided as well as two 4000 gallon underground lube oil tanks.

i. Waste Heat Coolers

Provision is made to dissipate excess heat generated in the plant by use of dry coolers for the engine jacket water and for the engine oil.

j. Control and Monitoring System

The central control and monitoring system is comprised of (1) a central processing unit to scan the selected points as described in the flow diagrams, direct the gathering of information, process the data, and interface the peripheral devices; (2) an operator's terminal to provide man-machine interface, and; (3) a data logger to provide hard copy of all information in the system.

2. Operation

Diesel generators will operate to provide electricity to the plant as well as to the barracks complex. Electricity will be generated at 480V and transformed to 12KV to match existing distribution voltage. Normal loads will be handled by two generators with a third cutting in at peak loads. One generator will be available as standby in the event of breakdown or maintenance on one of the other units. Hot engine jacket water and water from the heat recovery muffler are fed directly to the power plant hot water supply main and through the main plant hot water pumps. Water from these pumps runs to the suction side of the boilers or will by-pass the boilers at periods of low

load. During the heating season, the boiler header line or the by-pass line from the plant pumps will supply directly to the distribution pump suction. If return from the distribution system is above 215^{o}F, the emergency heat exchanger and engine jacket dry cooler are activated to dissipate the excess energy and to provide engine jackets with cooling water at the proper temperature. Low temperature water from the lube oil cooler is sent directly to the food service facility building for domestic hot water generation or to the primary aeration tank. An emergency heat exchanger for excess heat dissipation is also provided for this system. During the cooling season, the base load is met by operation of the 118 ton electric driven centrifugal compressor while additional load is carried by the 622 ton absorption unit. Hot water continues to be supplied to the buildings to meet domestic hot water demand. The incinerator will normally operate 6 to 8 hours per day generating water temperatures of from 350^{o} to 450^{o}F. This water is retained in storage and is used for sludge drying or as a supplemental source of energy by connection to the plant hot water supply header. The computerized central control and monitoring system will provide complete control and monitoring of all major system componenets as to "on-off" status, alarms, safties and commandability. Nine basic sub systems are involved as follows: chiller system, boiler system, engine system, high temperature thermal loop, hot water supply system, primary loop cooling system, diesel fuel supply and storage system, plant air handling units and the oil cooler system. The system will also make continuous recordings of all elements involved in determining overall plant efficiency, plant load profiles, outdoor temperature and humidity and internal major equipment loadings. An analysis of the recorded data after a few seasons of operation will be instrumental in developing future design criteria. Of prime importance will be the overall plant load profiles which will impact greatly on future selection of prime movers,

relationships of sizes of chillers and boilers, extent of hot water storage, establishment of diversity factors and other design criteria. In addition, plant operation will provide data regarding maintenance and spare parts requirements, operator training needs, incinerator operation, and plant flexibility requirements and will highlight possible unanticipated operational problems. Outdoor temperature and humidity recording will permit data transfer to other similar facilities in different climatic areas. Over a period of time, operation of a demonstration plant will further provide information on plant reliability. This data will establish the need and extent for standby equipment and interconnection with public power facilities.

G. Expansion of Demonstration Plant Design

The purpose of the demonstration plant is to establish the feasibility and viability of the total utilities concept with the exception that, if these are proven, larger plants would be constructed to serve military facilities. It is anticipated that some problem areas will surface during demonstration plant operation but none are expected to be of such a nature that they cannot be resolved within current state of the art capabilities. In essence, the total utilities plant is merely a combination of utilities plants whose individual characteristics are well known but where interactions between the plants operating as a unit will require considerable analysis before larger plants are attempted. This analysis is, of course, a part of the overall program to be accomplished after plant shake down and sufficient operating experience has been achieved. There are some rather obvious areas, however, which should be addressed when one considers scaling from demonstration to prototype plant. These are as follows:

a. Load Profiles: As different ypes and larger numbers of structures are served by the plant, all of the load profiles (electrical, heating, domestic hot water, air conditioning and

sewage) will tend to become less subject to rapid and large fluctuations. Individual building loads and major equipment loads will comprise only a small portion of the overall plant load. This, together with the inherent diversity of a large complex, will result in relatively smooth load profiles which will be predictable with some consistency and accuracy. This predictability will tend to permit more confident design and more applicable operating procedures for the larger plants. Data from the demonstration plants should be very effective in establishing diversity factors for major complexes. A comparison of the profiles developed by computer with the actual loads on the demonstration plant will furnish working data in an area where such information is currently quite limited.

b. Plant Siting and Distribution Systems: Plant siting may be a problem as larger plants are constructed. A considerable land area may be required depending upon the type of sewage treatment selected, sludge drying area requirements, trash storage and processing needs and hot water and fuel storage tankage, special pollution control and heat dissipation equipment. Architecturally, the plant will present an industrial type appearance and so, in many cases, will be restricted to specific locations on a post or base. Once alternative sites have been established, a detailed analysis must be made to locate the major load centers with a view toward siting the plant to minimize distribution system losses. Determination should also be made at that time as to the installation of radial or loop distribution systems, distribution voltages, temperature and type of heating mediums, means of providing domestic hot water and determination as to whether individual buildings should be cooled from the central plant or with local equipment. In cases where a large portion of the buildings to be served are already existing, many of the above determinations will already have been made. Where new construction is basically involved, considerable study and analysis will be required to provide an optimal plant.

c. Equipment Design: As smoother and more accurate profiles are established and prototype operating experience is gained, the designer will have the opportunity to optimize operation and provide maximum plant flexibility through proper sizing of equipment. Many major items of equipment, such as boilers, generators, pumps and chillers, have the characteristic of lower efficiency at partial load operation. In large plant design, therefore, studies should be made to examine the effect on plant efficiency of installing small units to handle minimum loads which will commonly occur for long periods during the spring and fall seasons.

Another major determination involves selection of the type of pumping system to be installed where long water distribution lines are installed. Pumping costs, in such cases, can be a major economic factor in providing a cost effective plant. The study should include consideration of single speed and variable speed pumps and possible combinations of these types.

The sequential and parallel operation of units of different types and capacities most often requires special design considerations for proper functioning. This means a more complex design and installation and testing procedure than for the smaller demonstration plant. In addition, a more sophisticated operating manual, preventive maintenance program, a longer training period and greater spare parts inventory will be necessary. Where computerized control and operation are used, computer programming could become very intricate and costly.

d. Pollution Control: Pollution control design, equipment and processes for larger plants will normally be far more extensive and complex than for the demonstration plant. This is due to federal, state and local statutes which usually limit applicability of pollution criteria to larger items of equipment. In the bigger plants, particular attention may be required for NO_x, SO_x, particulate matter and other pollutants from the

generators, incinerators and boilers as well as heavy metals and other impurities from the sewage treatment process. Pollution control and monitoring equipment may constitute a major initial cost so the designer may wish to consider limiting maximum individual equipment size or taking action to acquire exemptions from excessive criteria. These actions will not only reduce initial costs but will tend to eliminate or reduce the requirement for additional monitoring, operating and maintenance effort needed for environmental control processes. Along these lines, increased care must be taken by the designer to meet noise level standards since decibel levels have a tendency to increase sharply with increased equipment size.

H. Potential Application for Military Facilities

Most military facilities offer an ideal mix of functional structures within a limited area which would in general present an excellent potential for total utilities application. Structures normally involved include troop housing, family housing, administration and training buildings, hospitals and medical facilities, community service and commercial buildings, storage buildings and maintenance and production facilities. This is quite different from the average civilian community in which large land areas are usually designated for specific purposes such as housing, commercial or industrial use. From the standpoint of load demands, the serving of many different functional structures will have the effect of reducing extreme peaks and valleys in the various types of energy requirements which could ordinarily reduce plant efficiency.

Perhaps the best available treatise on military facility energy usage is that prepared by Dr. H. D. Hollis and Captain A. V. Nida of the U.S. Army Facilities Support Agency, Fort Belvoir, Virginia. In their document "Characteristics of Energy Usage on Military Installations" dated 22 October, 1975, an overview of DOD installation use is provided. The projected

FY 75 world-wide consumption of energy sources in support of DOD installations was given as:

Electricity	Mwh	26,159,903	
	Mbtu	303,454,875	46%
Heating fuels	Bbl	30,378,130	
	Mbtu	178,281,166	27%
Propane gas	Mbtu	2,883,000	1%
Natural gas	Mbtu	112,672,000	17%
Coal	Tons	2,312,716	
	Mbtu	57,396,000	8%
Steam & Hot Water	Mbtu	1,766,000	1%
Total	Mbtu	656,453,041	100%

TABLE V

One of the long standing requirements of DOD is that an economic evaluation be made to determine the type of fuels to be used at any installation. The above figures, therefore, seem to indicate that the vast majority of our DOD installations are located where oil and gas are normally the prime source of energy. It can safely be assumed that these two fuels are also being used in most cases by utilities companies from which electricity is purchased for our military facilities. As indicated previously, the source of private utility power is one of the main considerations in determining where total utilities plants should be provided.

The other major general factor in determining whether a total utilities concept should be considered for a facility is the climatic conditions which establishes whether a relatively balanced summer cooling and winter heating load can be expected. In the past ten years, the DOD has relaxed criteria for air conditioning so that major summer loads are available in all but the extreme northern tier of states. As winter heating

loads in the southern states are low, it would appear that potential total utilities sites would normally be those in the borad mid-section of the country from coast to coast.

The above conclusions are, of course, generalities for which exceptions can be made for local conditions. It would appear, however, that the great majority of our installations would meet the basic requirements for at least serious consideration and study to determine whether a total utilities facility should be provided.

There are other factors which make a total utilities application highly feasible on military facilities. For new and future construction, almost all bases and posts maintain short and long term master plans which provide reasonable assurance as to future load requirements in the specific area to be served. Further, DOD criteria regarding "U" factors, fenestration and other energy related design factors rather firmly define construction quality thus permitting substantially valid energy usage estimation. For existing construction, the long standing policy of providing small central heating and cooling plants to serve well defined areas of a base or post again permits accurate analysis and offers a means of providing a total utility or a modified total utility plant by modification or extension of the existing plant. Land area is usually available and distribution lines are already installed making such conversion relatively simple and economically viable.

Military facilities offer another advantage in that most posts are staffed with maintenance and operating personnel who are familiar with power generating and heat transfer equipment and have the capability of performing preventive maintenance and operating adjustments to insure proper plant performance.

Trash disposal from military facilities is often accomplished by contract at rather high cost. The recovery of energy from this waste could, in large part, eliminate this expense

and contribute substantially to conservation of critical fuels. In commercial incineration applications, much of the expense is due to the requirement to separate trash to eliminate metals, non-combustibles and other undesirable materials. Because of the control of the Commanding Officer, such separation can be done at the source this eliminating the need for expensive and high maintenance cost separation and handling equipment at the plant.

In general, military facilities appear to be ideally suited for a total or partial utilities plant installation. Pending verification of the theoretical energy savings, we would recommend that new construction planning and siting be such that new central plants can be modified and expanded to employ the total utilities concept in those areas where analytical studies so dictate.

I. Automated Control Systems

Recently, considerable emphasis has been placed on the use of automated control systems for operation and maintenance of utilities at military facilities. As a result, many Army posts and stations are installing such controls on existing as well as new construction. Control systems are usually justified by savings in energy and maintenance costs but also may involve security monitoring, fire protection, life safety and load management features. Therefore, before proceeding with a design of a total utilities plant at a specific location, the probability of the installation of automated controls should be examined and a general evaluation made as to the possible effect of such an installation on the plant design. If this effect is significant, it may be necessary to make a firm decision on control installation prior to commencing with plant design.

Automated control systems vary in sophistication from simple on-off time clocks to central programmed computer systems. These control concepts are discussed in detail in a USAFESA

publication titled "Automation and Centralization of Facilities Monitoring and Control Systems". Regardless of the complexity of the operation of the control systems, the results from an energy standpoint can be assumed to be equivalent and the effect on load profiles relatively stable. The results of automated control operations have, as yet, not been quantified so that load profile changes must currently be based on judgement. However, data is being gathered at operating facilities and firm figures should be available after a few seasons of operation.

Basic schemes used in automated control systems are as follows:

1. Equipment Shutdown: This scheme involves the programmed shut-off of building heating and cooling equipment during unoccupied periods. The fundemental approach is to cut off all fans, pumps, compressors and other pertinent equipment when the building is not being used and to allow room temperatures to drift. The systems are reactivated in time to recover room temperatures before occupancy is resumed. Maximum energy savings are chieved when the systems are reactivated no sooner than is necessary to recover room temperature. The figure below gives a general indication of the effect of this scheme on an office building during an average winter work day.

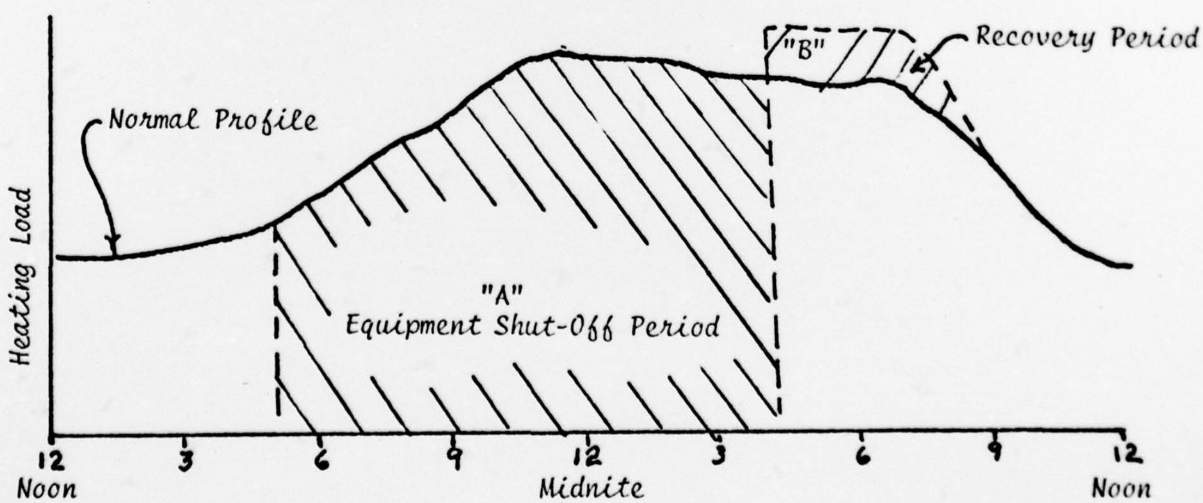


Figure 2

It is apparent from the above that the total energy savings will be the area "A" minus area "B". Of more significance, however, to the total utilities plant designer, is the new shape of the profile which shows relatively long periods of no load and full load operation. These periods become even more promounced during weekend and holiday periods. Where numerous buildings using this scheme are a major part of a complex served by a total utilities plant, the changes to the gross plant profile will be important. In colder climates, care must be taken to insure that during the shut-down period, temperatures in the building will not fall below freezing and the profile should be adjusted to show periods of heating to maintain a minimum set temperature. Profiles similar to the above should be developed and evaluated for the cooling season and revisions made to the electrical profile which will be affected by the shut-off of pumps, fans, compressors and other electrical equipment.

2. Outside Air Shut-Off: Programmed shut-off of outside air consists of closing outside air intakes and shut down of exhaust fans when the building is unoccupied. This will normally be done in conjunction with the equipment shut down cycle described above. However, when the equipment is started to pre-heat the building prior to occupancy, the outside air will remain shut off until shortly before the building is open to personnel. This will have the effect of lengthening the equipment shut off period and shortening the maximum load period in the early morning. Outside air reduction, although not an integral part of an automated control system, is often considered and implemented during installation of controls. Indications ar that many building systems have been designed to draw in more outside air than is required for adequate ventilation and, therefore, the minimum outside air damper setting can be adjusted to reduce load. This action will have

little effect on the shape of the load profile, but will change the magnitude of the load curve.

3. There are many other control systems available in addition to the two above, such as; enthalpy control, enthalpy optimization, temperature reset, chiller loading, load management and peak reduction. Profile changes resulting from these systems, however, are random in nature, difficult to predict and, therefore, are of minor significance as to their effect on load profiles. These systems can, therefore, be ignored in the overall evaluation.

An example of the effect of equipment shut-down and outside air cut-off can be shown by examination of the Ft. Belvoir heating load data. The loads shown are for maximum design outdoor conditions and thus are not typical or average. However, they are adequate for demonstrating the impact of ACS systems on load profiles.

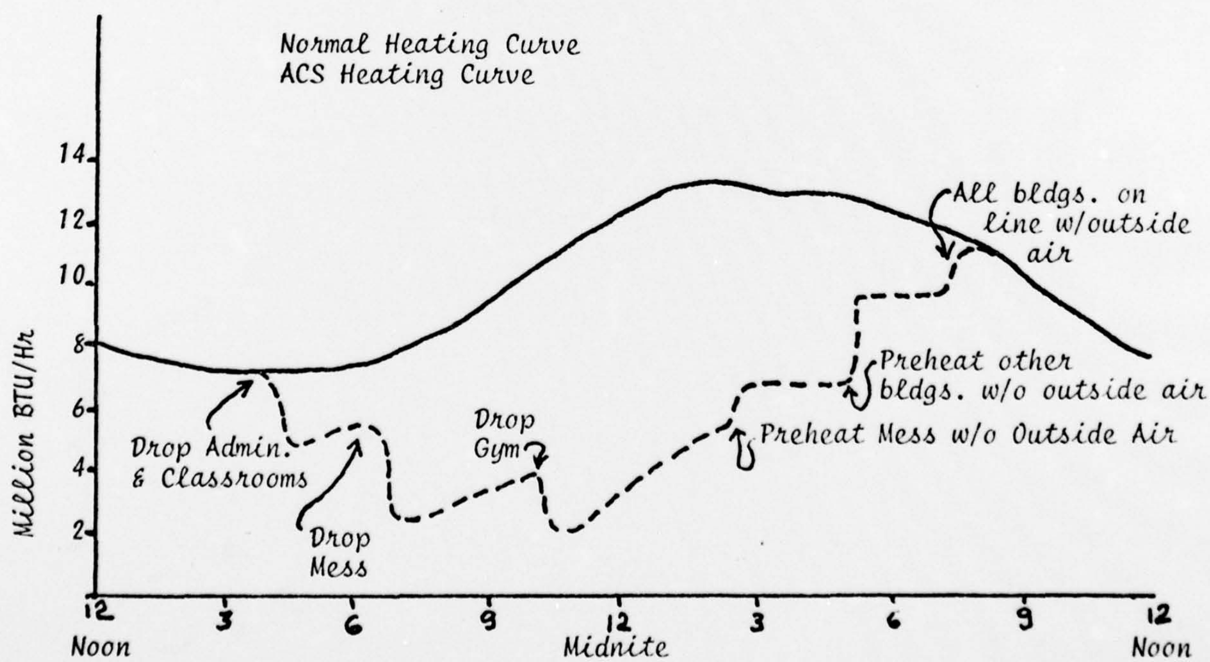
FT. BELVOIR BARRACKS COMPLEX
HEATING LOADS

Bldg. No.	Building Descr.	Transmission Load BTU/Hr	Infiltration Load BTU/Hr	Outside Air Load BTU/Hr
1 thru 6	EM Barracks Bldgs. 18 Modules (BCD) & (ACD) types	4,319,392	1,190,096	1,621,365
7	Dispensary Group Bldg.	88,377	21,425	31,400
8	Branch Exchange	122,400	21,425	163,800
9 thru 10	Two- (3) Company Admin. Bldgs. Office and Storage	481,670	257,047	73,926
11	(4) Company Admin. Bldg. Office and Storage	307,485	147,970	49,248
12	Second Battalion HQ. and Classroom Bldg.	266,600	96,095	160,670

13	Headquarters Bldg. Regimental Brigade	157,720	62,730	47,710
14	Food Service Facility	289,120	116,717	2,266,950
15	Unit Chapel Bldg.	211,030	100,530	184,680
16	Gymnasium Bldg. (No Air Conditioning)	471,670	362,577	1,606,716
	TOTALS	6,715,464	2,082,710	6,206,411

TABLE VI

The heating load data above shows that the maximum load on all the buildings under normal operating condtions (without ACS) is approximately 13 million BTU/Hr. This is arrived at by adding the transmission and outside air loads. The infiltration load is not considered since outside air infusion will tend to pressurize the buildings and minimize infiltration. A normal working day profile during design outdoor winter conditions is shown below.



HEATING PROFILES - FT. BELVOIR BARRACKS
-DESIGN WINTER DAY-

Figure 3

As can be seen from the chart and figure above, the prime impact of equipment shut-down and outside air shut-off is provided by loads in the mess facility and the gymnasium. These two buildings account for about thirty to forty percent of the load reduction while the remainder of the structures (except for barracks) reduce the load beyond the fifty percent mark. During early morning warm-up, the outside air remains shut off until occupancy, thus permitting heat build up with only the infiltration load.

Although the figures show considerable savings in energy with proper application of ACS, it should be noted that probably only minor reductions in equipment sizing will result. At about 8 AM with all buildings on the line, the overall heating load is quite close to the maximum of 13 million BTU/Hr. The major impact of the ACS systems on plant design will, therefore, most likely be in plant operation, design flexibility and heat storage.

With the ACS systems, it is apparent that from 8 to 12 hours during the 24 hour day, the heating load is drastically reduced. However, it must be remembered that during that period, the electrical load is also reduced because of shut off of the many fans, pumps and other power consumers associated with the heating systems. It can be supposed, therefore, that during extreme cold weather, there will always be an adequate heating load to constructively use all of the heat that is generated. In milder weather, however, there may be long periods when such loads are not available. During these times, plant operation should be sufficiently flexible to permit storage of such heat or in-plant use of the heat for operations such as sludge drying, sewage treatment and water recycling. The operational concept will have a major impact on sizing of the heat storage system and timing of incinerator operation.

Another consideration of importance in the combination of ACS and the total utilities concept is that a means should

always be provided for overriding the ACS when an excess of heat is being generated by the total utilities plant. Rather than wasting the excess energy, the building preheat cycles should be turned on prematurely and the facilities brought up to temperature in a more gradual time frame. This will have the effect of smoothing out the heating profiles from midnite to early morning.

In conjunction with ACS, mention should be made of integration of the control systems with solar installations and variable fresh air control.

Solar installations may involve collection and distribution at individual buildings, large collection fields feeding the central plant or both. The ACS is ideally suited for controlling and maximizing efficiency of the overall system by permitting the operator to make necessary adjustments as the quantity of solar heat varies. The effect of solar assist on the load profiles will change considerably due to weather conditions and will, therefore, require more flexibility in the total utility plant design. In most cases, this will result in the need for heat storage provisions which otherwise might not be required.

Fresh air demands for buildings have been subject to review in recent years primarily because of their effect on overall building loads and fuel consumption. As can be seen from Table VI, outside air comprises about 50 percent of the overall heating load. In buildings where heavy occupancy occurs on an occasional basis, such as a gymnasium or a mess hall, many designers provide the full quantity of fresh air continuously. The ACS permits the operator to vary outside air quantity depending on actual occupancy. Further study in this area is also needed to determine whether the standard 7½ to 10 CFM per person normally used in design is, in fact, necessary or whether

it could be reduced without appreciable effect on health or comfort. Suitable reduction and control of outside air with ACS should provide a major reduction in load which could reduce initial total utilities installation costs and improve even further system efficiency.